

Claims

1. An electro-active actuator having a bender construction comprising layers of electro-active material and electrode layers for activation of the electro-active material, the layers of electro-active material being shaped to extend continuously along at least one curved portion and at least one substantially flat portion arranged with electrical terminals for electrical connection to the electrode layers.
2. The electro-active actuator of claim 1, wherein the curved portion forms a helix arranged, on actuation, to bend around the axis of the helix.
3. The electro-active actuator of claim 2, wherein the helix formed by the curved portion is itself curved.
4. The electro-active actuator of any one of the preceding claims, wherein the flat portion extends tangentially from the curved portion.
5. The electro-active actuator of any one of the preceding claims, wherein the flat portion has a length equal to or exceeding an outer diameter of the curved portion.
6. The electro-active actuator of any one of the preceding claims, wherein the electrical terminals are located on the same face of the flat portion.
7. The electro-active actuator of any one of the preceding claims, wherein the electro-active material is a ceramic material.
8. The electro-active actuator of any one of the preceding claims, wherein the substantially flat portion is arranged as a projecting tab.

9. An electro-active actuator having a bender construction comprising layers of electro-active material and electrode layers for activation of the electro-active material, the layers of electro-active material being shaped to extend continuously along at least one curved portion and at least one substantially flat portion.

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10. A method of manufacturing an electro-active actuator according to any one of the preceding claims, the method comprising:

preparing a ceramic tape in a green state;

placing said tape into a former having a section to support said flat portion

10 and maintain the orientation of said flat portion with respect to the permanently curved portion of the actuator; and

drying said tape within said former to reduce the plasticity of said tape.

11. The electro-active actuator of claim 1, comprising a single curved portion  
15 curving around an axis and arranged, on actuation, to bend around the axis, and at least one flat portion extending away from the axis.

12. The electro-active actuator of claim 11, wherein the curved portion has a substantially uniform shape parallel to the axis.

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13. The electro-active actuator of claim 11 or 12, wherein the flat portion extends radially away from the axis.

14. The electro-active actuator of any one of claims 11 to 13, wherein the curved  
25 portion has a cross-section perpendicular to the axis which is substantially a section of a circle.

15. The electro-active actuator of any one of claims 11 to 14, wherein the layers  
30 of electro-active material being shaped to extend continuously from the first mentioned curved portion to said straight portion along a second curved portion

having a curvature of opposite sign from said first curved portion.

16. The electro-active actuator of any one of claims 11 to 15, wherein the electro-active material is a ceramic material.

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17. An electro-active actuator having a bender construction comprising layers of electro-active material and electrode layers for activation of the electro-active material, the layers of electro-active material being shaped to extend continuously along a curved portion curved around an axis and arranged, on actuation, to bend  
10 around the axis, and along at least one substantially flat portion extending away from the axis.

18. A ceramic actuator comprising a first curved section extending radially into a second, essentially flat section.

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19. The ceramic actuator of claim 18 having a single curved section bowed inwardly with a short outwardly bowed portion that extends into the flat section.

20. The ceramic actuator of claim 18 or 19 formed from a continuous sheet of  
20 piezoelectric material.

21. A loudspeaker for audible sound comprising a sound emitting element mounted onto a support structure and at least one actuator as claimed in any one of claims 11 to 20 being mounted at a proximate edge onto said sound emitting element  
25 and a distal edge onto said support structure.

22. The loudspeaker of claim 21 having a compliant sealing element or elements around the edges of the sound-emitting element.

30 23. The loudspeaker of claim 21 or 22, wherein the second flat section with the

distal edge is mounted onto a part of the support structure while the first curved section with the proximate edge is mounted onto the sound-emitting element such that said curved section bridges a gap between said sound emitting element and said support structure.

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24. The loudspeaker of any one of claims 21 to 23, wherein the support structure and the sound generating element are parts of the outer shell of a portable data handling or communication device.

10 25. The loudspeaker of any one of claims 21 to 24, wherein the second flat section extends in a longitudinal direction into a rectangular shape.

26. The loudspeaker of any one of claims 21 to 25, wherein the second flat section terminates as two or more flat portions.

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27. The electro-active actuator of claim 1, comprising a single curved portion and two flat portions extending tangentially from opposite ends of the curved portion, at least one of which is arranged with said electrical terminals for electrical connection to the electrode layers.

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28. The electro-active actuator of claim 27, wherein the two flat portions are substantially parallel to each other.

29. The electro-active actuator of claim 27 or 28, wherein the straight portions are  
25 each arranged, on actuation, to bend in a sense opposite from the curved portion.

30. The electro-active actuator of claim 27 or 28, wherein the straight portions are each poled in a direction opposite from the direction in which the curved portion is poled.

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31. An electro-active actuator having a bender construction comprising layers of electro-active material and electrode layers for activation of the electro-active material, the layers of electro-active material being shaped to extend continuously along a curved portion and two flat portions extending tangentially from opposite  
5 ends of the curved portion.

32. A ceramic actuator comprising an arcuate middle section extending tangentially into two essentially straight end sections.

10 33. A loudspeaker for audible sound comprising a sound emitting element mounted onto a support structure and at least actuator as claimed in any one of claims 27 to 32 being connected to said sound emitting element and a support, wherein the sound emitting element is connected to an end portion of one of the flat portions and the actuator is mounted with an end portion of the other flat portion connected to the  
15 support.

34. The loudspeaker of claim 33 having a compliant sealing element or elements around the edges of the sound-emitting element.

20 35. The loudspeaker of claim 33 or 34, wherein sound emitting element is a flat or slightly curved transparent panel.

36. The loudspeaker of any one of claims 33 to 35, wherein the support structure and the sound generating element are parts of the outer shell of a portable data  
25 handling or communication device.

37. A method of manufacturing an actuator in accordance with any one of claims 27 to 32, the method comprising:  
manufacturing deformable sheets of pre-cursor material;  
30 applying a first, a second and a third electrode onto the sheets;

stacking said sheets such that at least one first, second and third electrode overlay to form a layer of bimorph tape;

pressing the bimorph tape into the shape of the actuator; and

sintering the shaped tape,

5 wherein two of the three electrodes have gaps at locations corresponding to areas between adjacent sections of the actuator and one of the three electrode is continuous across the areas.

38. The method of claim 37, further comprising the step of poling the straight  
10 portions of the actuator oppositely to the curved portions.

39. The electro-active actuator of claim 1, wherein the curved portion forms a helix arranged, on actuation, to bend around the axis of the helix, which helix is itself curved to have two sections of opposite curvature with rotational symmetry about the  
15 point between the two sections.

40. The electro-active actuator of claim 39, comprising a single curved portion.

41. The electro-active actuator of claim 40, including a said flat portion arranged  
20 with electrical terminals for electrical connection to the electrode layers at one end of the curved portion.

42. The electro-active actuator of claim 41, including a further substantially flat  
25 portion at the other end of the curved portion.

43. The electro-active actuator of claim 42, wherein said further flat portion at the other end of the curved portion is arranged with electrical terminals for electrical connection to the electrode layers.

30 44. The electro-active actuator of claim 42 or 43, wherein the actuator is mounted

to a first object at said point between the two sections and to a second object by said first mentioned flat portion and said further flat portion.

45. The electro-active actuator of any one of claims 39 to 44, wherein said two  
5 sections of opposite curvature are substantially sections of a circle.

46. An electro-active device having a continuous electro-active member  
extending along a minor axis which is curved, the continuous electro-active member  
curving around the minor axis and arranged with electrodes to bend, on activation,  
10 around the minor axis, thereby to twist around the minor axis concomitantly with  
relative displacement of portions of the device out of the plane of the curve, wherein  
the minor axis follows a curve having two sections of opposite curvature with  
rotational symmetry about the point between the two sections.

15 47. The electro-active actuator of claim 46, wherein the continuous electro-active  
member curves around the minor axis in a helix.

48. The electro-active actuator of claim 46 or 47, wherein the minor axis follows  
a curve having a single change in curvature at said point between the two sections.  
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49. The electro-active actuator of any one of claims 46 to 48, wherein the actuator  
is mounted to a first object at said point between the two sections and to a second  
object at the opposite ends of said two sections.

25 50. The electro-active actuator of any one of claims 46 to 49, wherein said two  
sections of opposite curvature are substantially sections of a circle.

51. An electro-active actuator adapted to move objects in a straight line, said  
actuator having at least one group of coupled actuator sections with each of said  
30 sections having a structure of electro-active material extending around a minor axis

which is permanently curved and wherein the structure of electro-active material includes successive electro-active portions having electrodes to bend , when activated, around the minor axis, and said sections being coupled by a joint element and arranged in a rotational symmetry about said joint element.

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52. The electro-active actuator of claim 51, wherein the actuator sections within each group move, when activated, parallel to one another while balancing out motions in other directions.

10 53. The electro-active actuator of claim 51 or 52, wherein the actuator sections within each group are essentially identical.

54. The electro-active actuator of any one of claims 51 to 53, wherein each section comprises a continuous electro-active element extending along and curving  
15 around the minor axis.

55. The electro-active actuator of claim 54 wherein the continuous electro-active element curves around the minor axis as a helix.

20 56. The electro-active actuator of any one of claims 51 to 55, having at least two actuator sections of opposite curvature coupled by the joint section.

57. The electro-active actuator of claim 55, wherein the two actuator sections of opposite curvature are formed from one continuous tape of electro-active ceramic  
25 material.

58. The electro-active actuator of claim 57, wherein the two actuator sections and the joint section are formed from one continuous tape of electro-active ceramic material.

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59. The electro-active actuator of any one of claims 51 to 56, wherein the joint section comprises a hetero material.

60. The electro-active actuator of claim 59, wherein the joint section is adapted to  
5 be relatively stiff in all but one direction.

61. The electro-active actuator of any one of claims 51 to 60, wherein all actuator sections within one group are adapted to receive essentially identical activation signals.